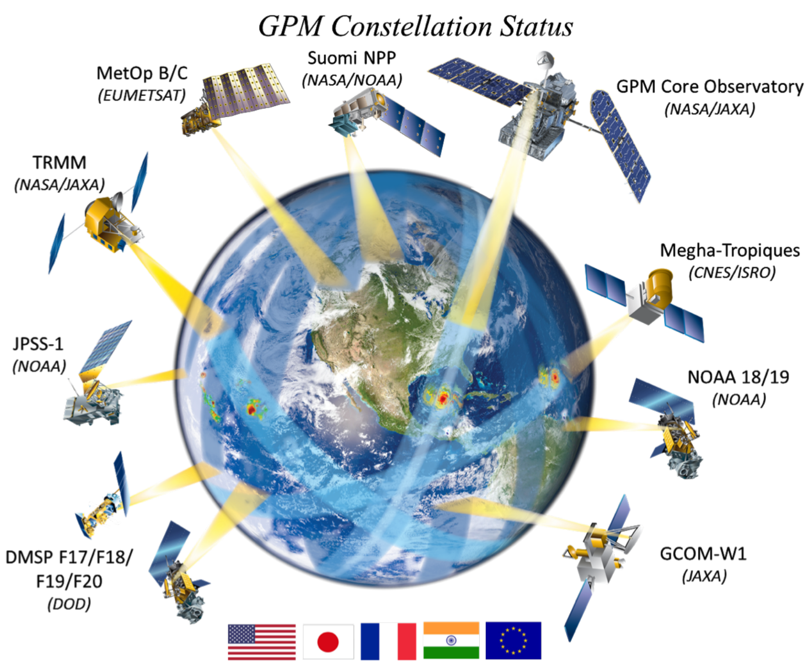
The GPM Microwave Imager & Constellation : Algorithm Status



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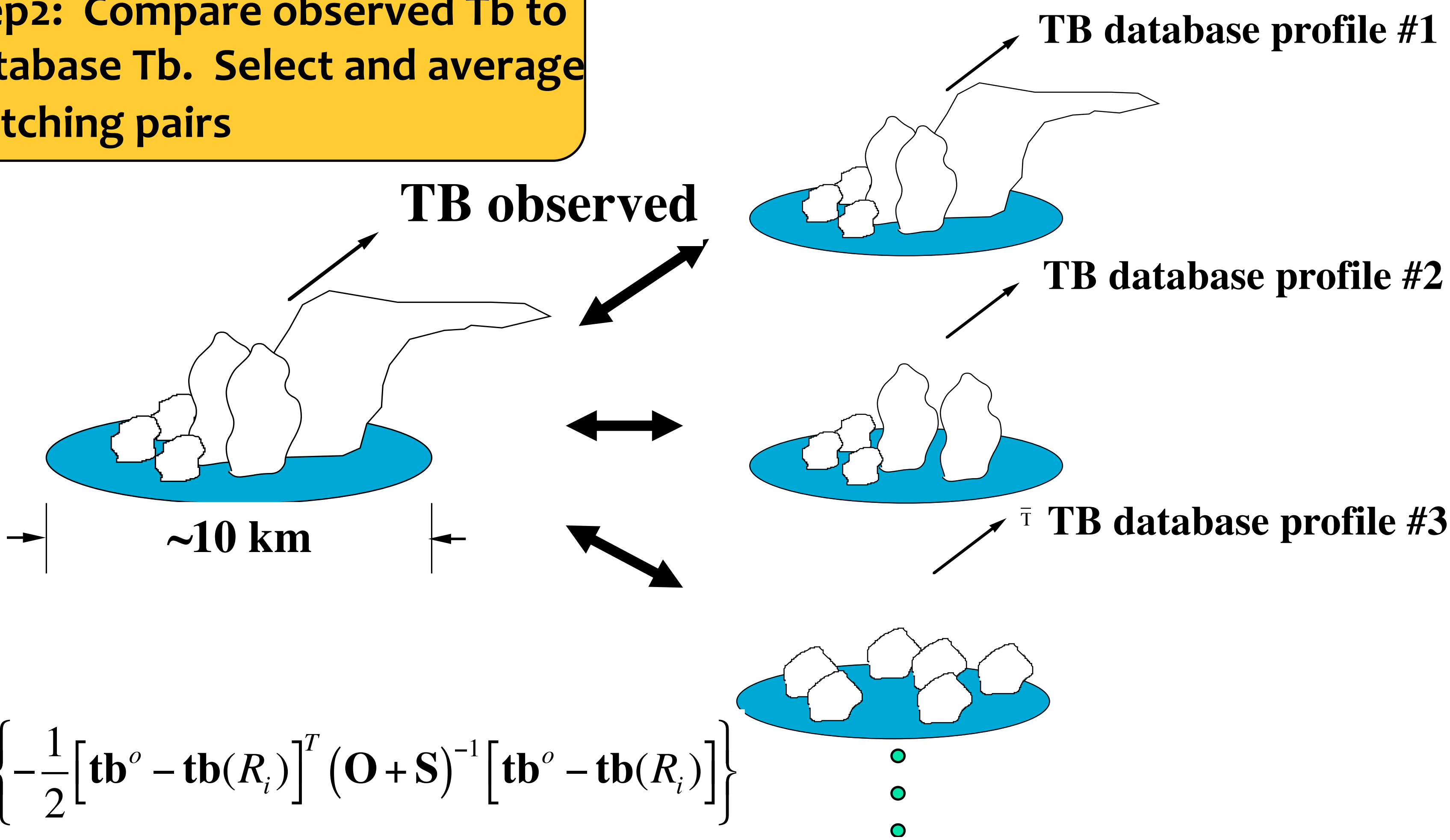
PMM Science Team Meeting
October 9, 2018
Phoenix, AZ

The GPM radiometer algorithm

Step 1: Use GPM Satellite to derive set of "Observed" profiles that define an a-priori database of possible rain structures.

Step2: Compare observed Tb to Database Tb. Select and average matching pairs

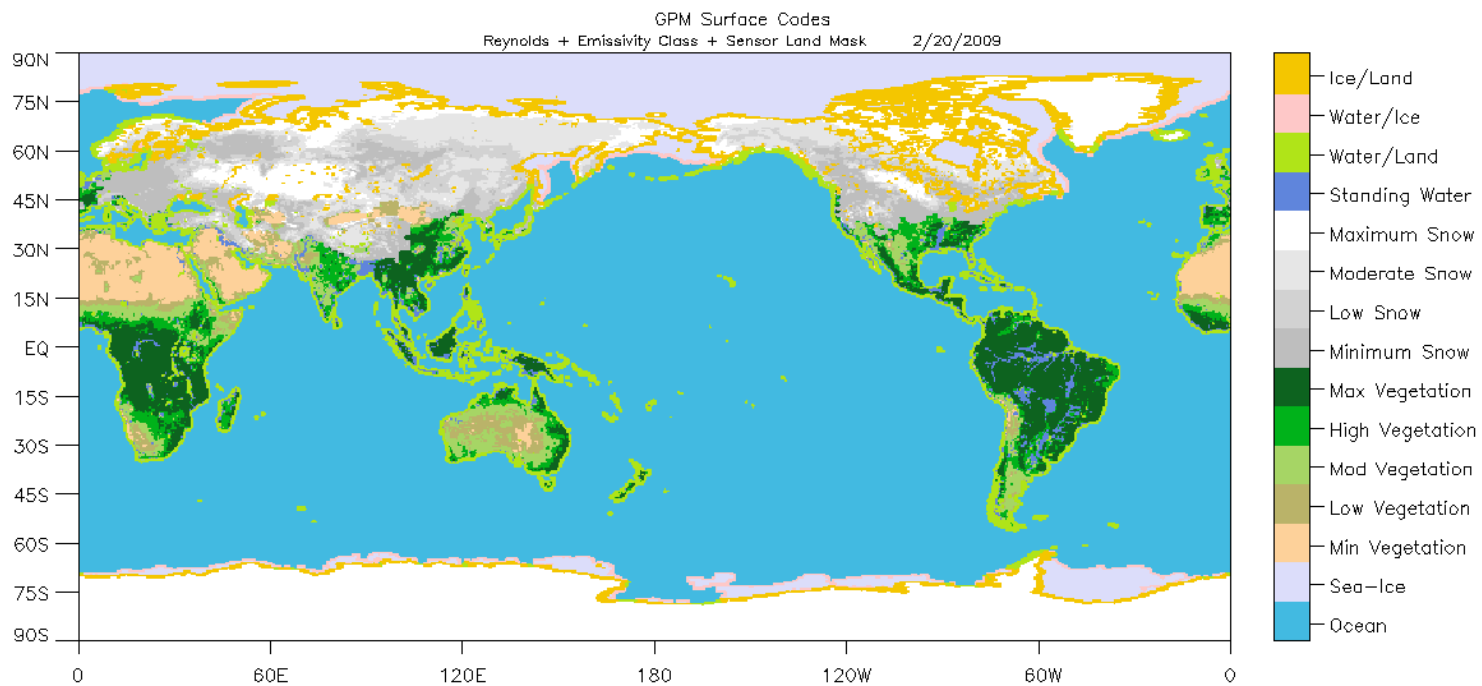


$$J_i = \exp\left\{-\frac{1}{2}\left[\mathbf{tb}^o - \mathbf{tb}(R_i)\right]^T (\mathbf{O}+\mathbf{S})^{-1}\left[\mathbf{tb}^o - \mathbf{tb}(R_i)\right]\right\}$$

GPROF 2014 Database Divisions

For Operational Algorithm:

Do not to mix different surface types
Do not to mix different T_{2m} or TPW

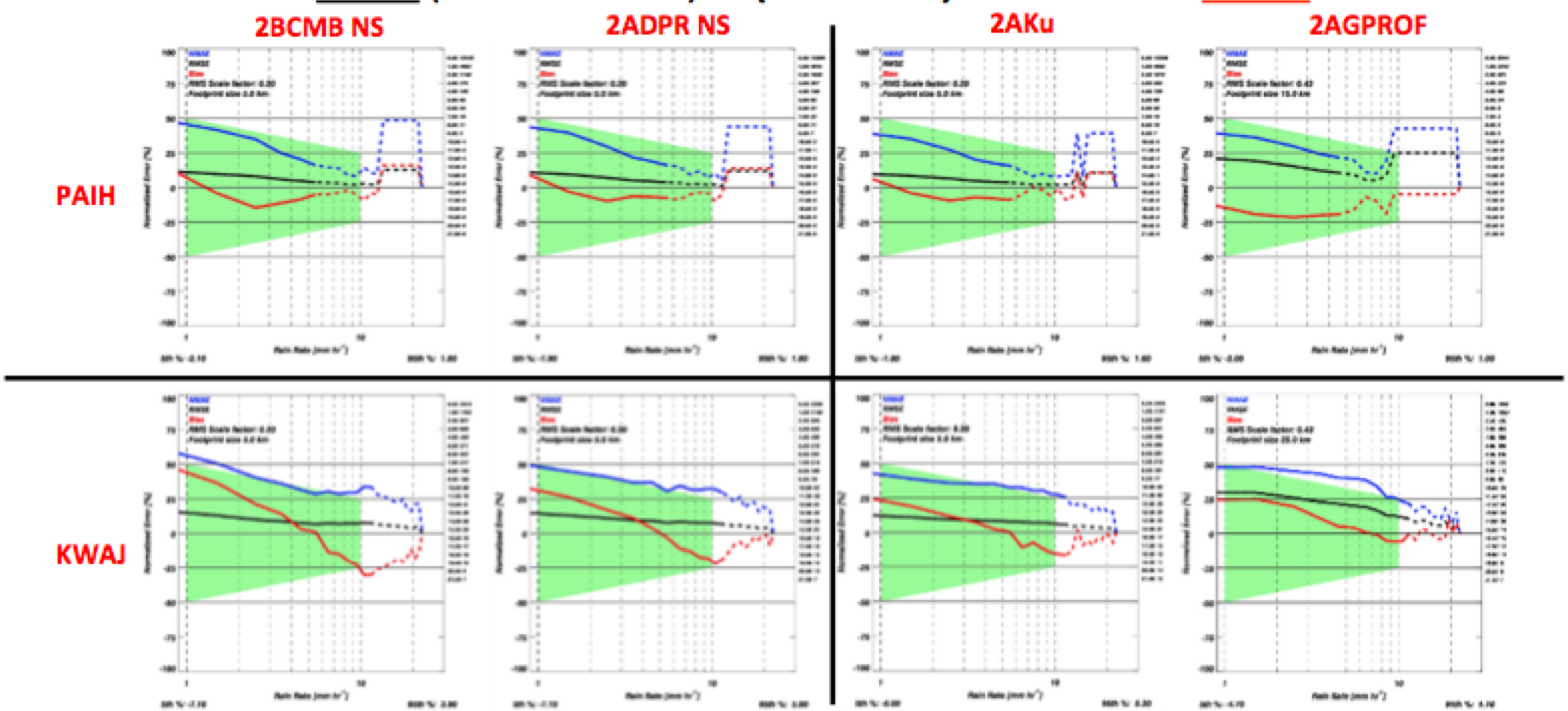


GPROF 2017: aka GMI version 5

- Over oceans, uses “Combined V04” rainfall + additional hydrometeor adjustments to get better Tb match at higher GMI frequencies.
- Uses GMI to extend rain rates to lower thresholds than detectable by DPR. Cloud Water is converted to drizzle to match CloudSat rain occurrence.
- Over land, uses “DPR Ku V04” rainfall + additional hydrometeor adjustments to get better Tb match at higher GMI frequencies. Issue gone w. Combined V05 and V06.
- Over snow covered surfaces, uses “MRMS matchups with individual satellites” for a-priori databases
- Sets precipitation threshold to match rain occurrence in a-priori database. i.e. in each TPW and Water vapor bin, probability of rain is the same as Combined.

Quantitative validation over Alaska and Kwajalein

Ocean (PAIH and KWAJ) **L1 (50 x 50 km) Rain Rates for ITE114**

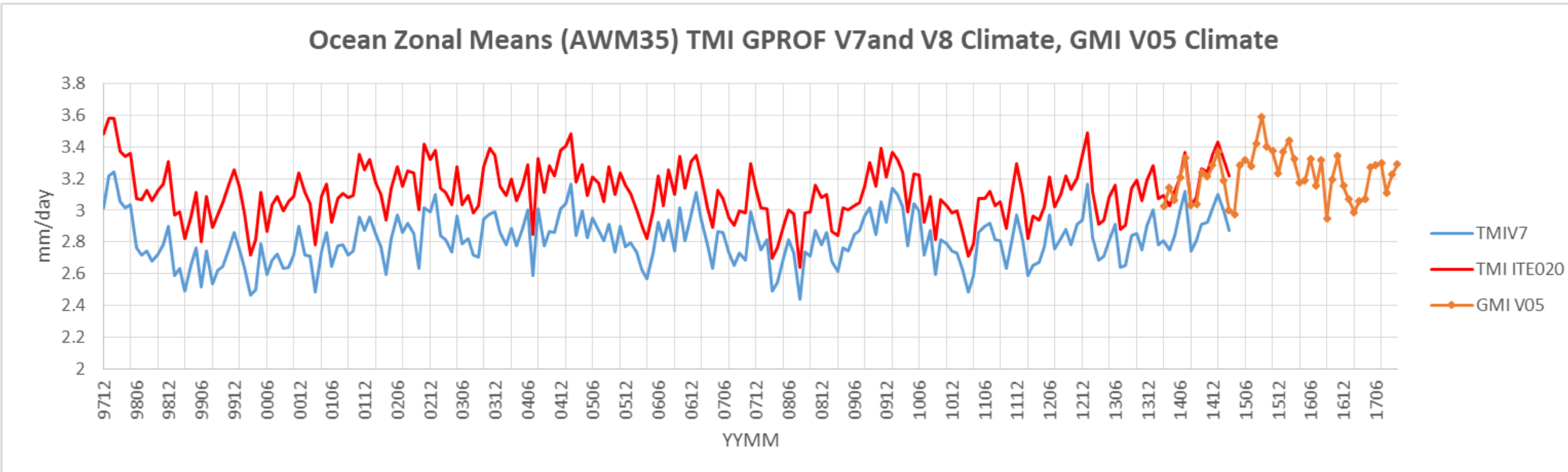


All meet L1 and most improved from V4 to some degree (*in the net*). DPR NS/MS over Kwaj about the same between versions. Regime and/or sampling affects the trends between PAIH and KWAJ. (Kwaj sampling less robust)

Beam filling impacts these trends…..more so for GPROF………..

GPM Expanded Time Series

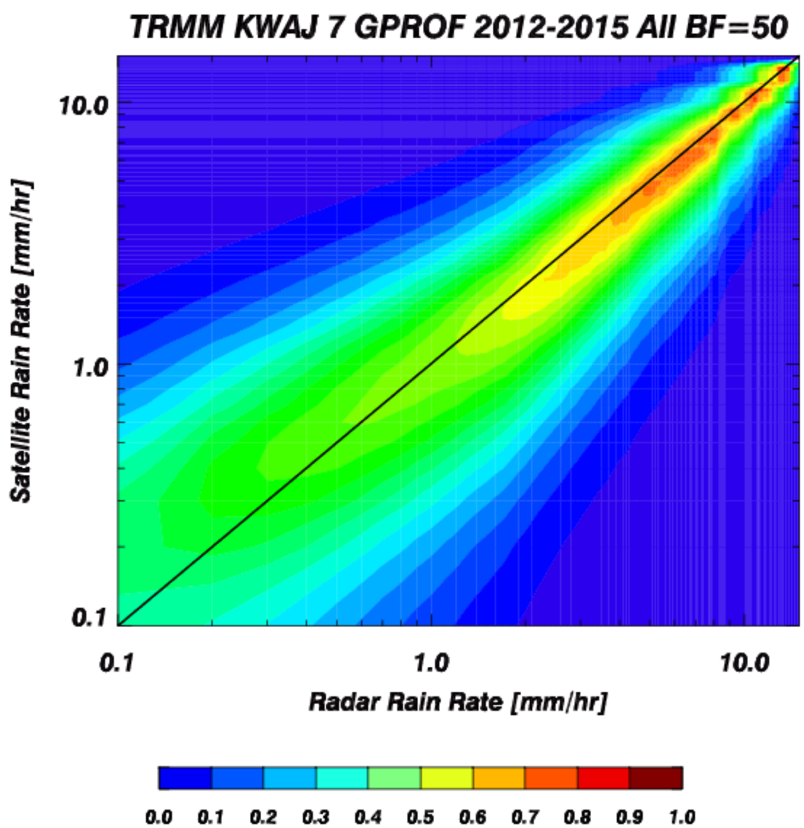
TMI → GMI time series



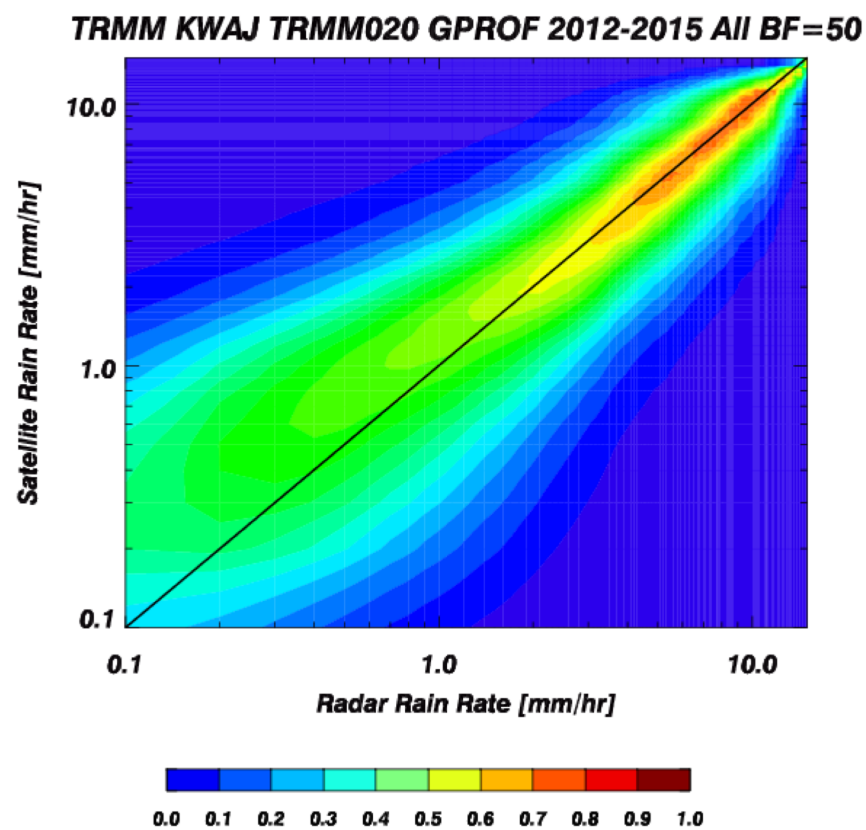
Time series of global mean shows increase in rainfall over oceans, with new TMI GPROF results consistent with GMI V05.

2D Heidke Skill Score - KWAJ

V7



V8



Symmetry around the 1:1 line indicates good correlation between the two estimates. Best agreements in orange/red from approximately 3-13 mm hr^{-1}.

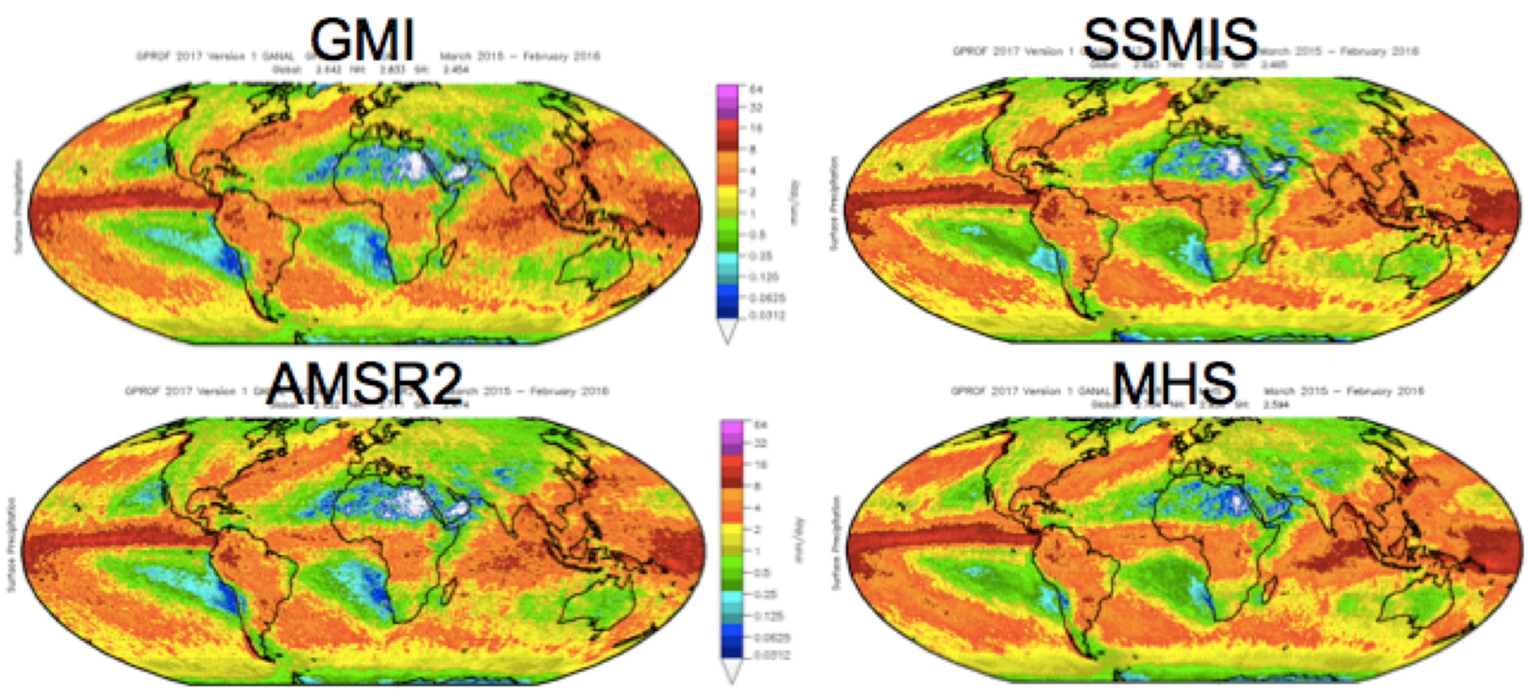
V5 Constellation

For GPM and TRMM eras

GMI	Mar 2014	Active
AMSR2	Jul 2012	Active
SSMIS-F16	Nov 2005	Active
SSMIS-F17	Mar 2008	Active
SSMIS-F18	Mar 2010	Active
SSMIS-F19	Dec 2014	Feb 2016
MHS/NOAA-18	May 2005	Active
MHS/NOAA-19	Feb 2009	Active
MHS/MetOp-A	Dec 2006	Active
MHS/MetOp-B	Apr 2013	Active
ATMS/NPP	Dec 2011	Active
ATMS-JPSS-1	Nov 2017	Active
TMI	Nov 1997	Apr 2014
AMSR-E	May 2002	Oct 2011
SSMI-F11	Nov 1991	May 2000
SSMI-F13	May 1995	Nov 2009
SSMI-F14	May 1997	Aug 2008
SSMI-F15	Feb 2000	Aug 2006*
AMSU-B/NOAA-15	Jan 2000	Sep 2010
AMSU-B/NOAA-16	Oct 2000	May 2010
AMSU-B/NOAA-17	Jun 2002	Dec 2009

V5 Current Status

- Largely consistent across sensors
- Seamless transition between sfc types and regimes
- Mechanics are largely solved except for error covariance
- Matching climatology of a-priori
- Regional errors largely from lack of information content



GPROF 2019: aka GMI version 6

- Will simplify and codify the a-priori database creation as much as possible. Philosophy is to take GPM Combined output whenever possible. Diverge only when necessary.

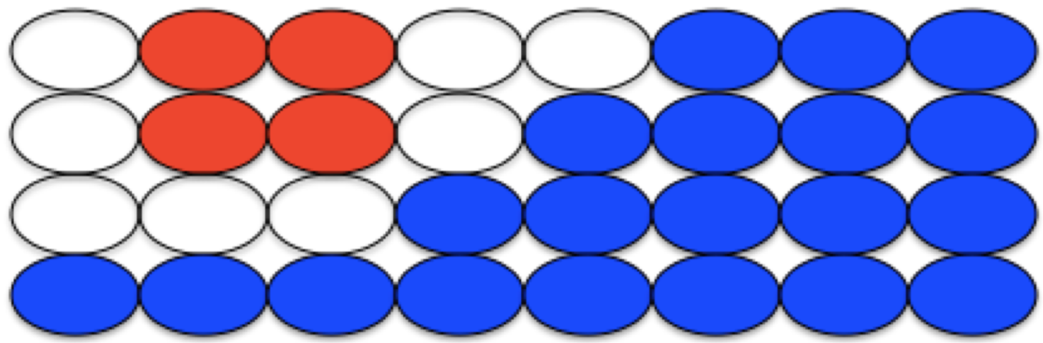
- No significant changes in retrieval approach, except for
  - Improved error covariance formulation
  - Convective/Stratiform separation
  - Additional ancillary data
    - Improved Orographic precipitation improvement
    - High latitude drizzle

A-priori database

(The easy part)

- Populate N orbits of PR pixels with DPR output, where DPR observes radar echo and thus activates retrieval.
- Run GMI Optimal Estimation algorithm when no rain is present (currently oceans only). For pixels that converge, map water vapor and cloud water profile to PR pixels. Use GANAL to redistribute cloud water if no layer information is retrieved.
- Use DPR-CMB with OE results and interpolate surface properties, water vapor and clouds out to 30 km.
- Fill remaining pixels with GANAL surface and atmospheric properties.

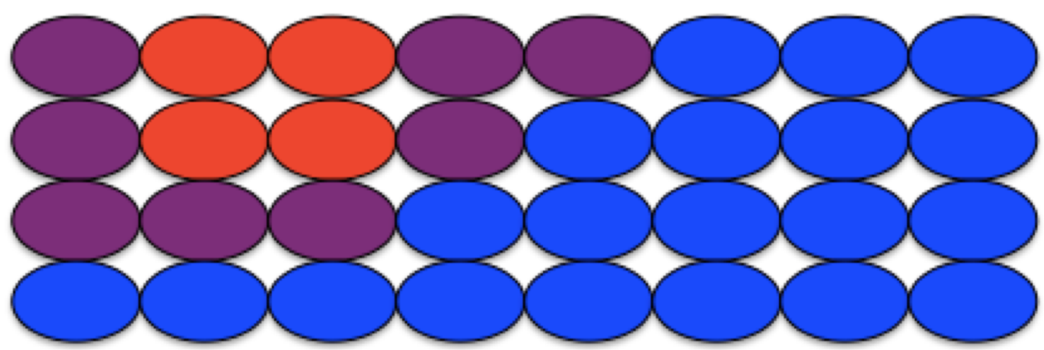
A-priori database



Combined DPR/GMI Profiles

OE GMI only profiles – non raining ocean only for now

Interpolation to 30 km



A-priori database

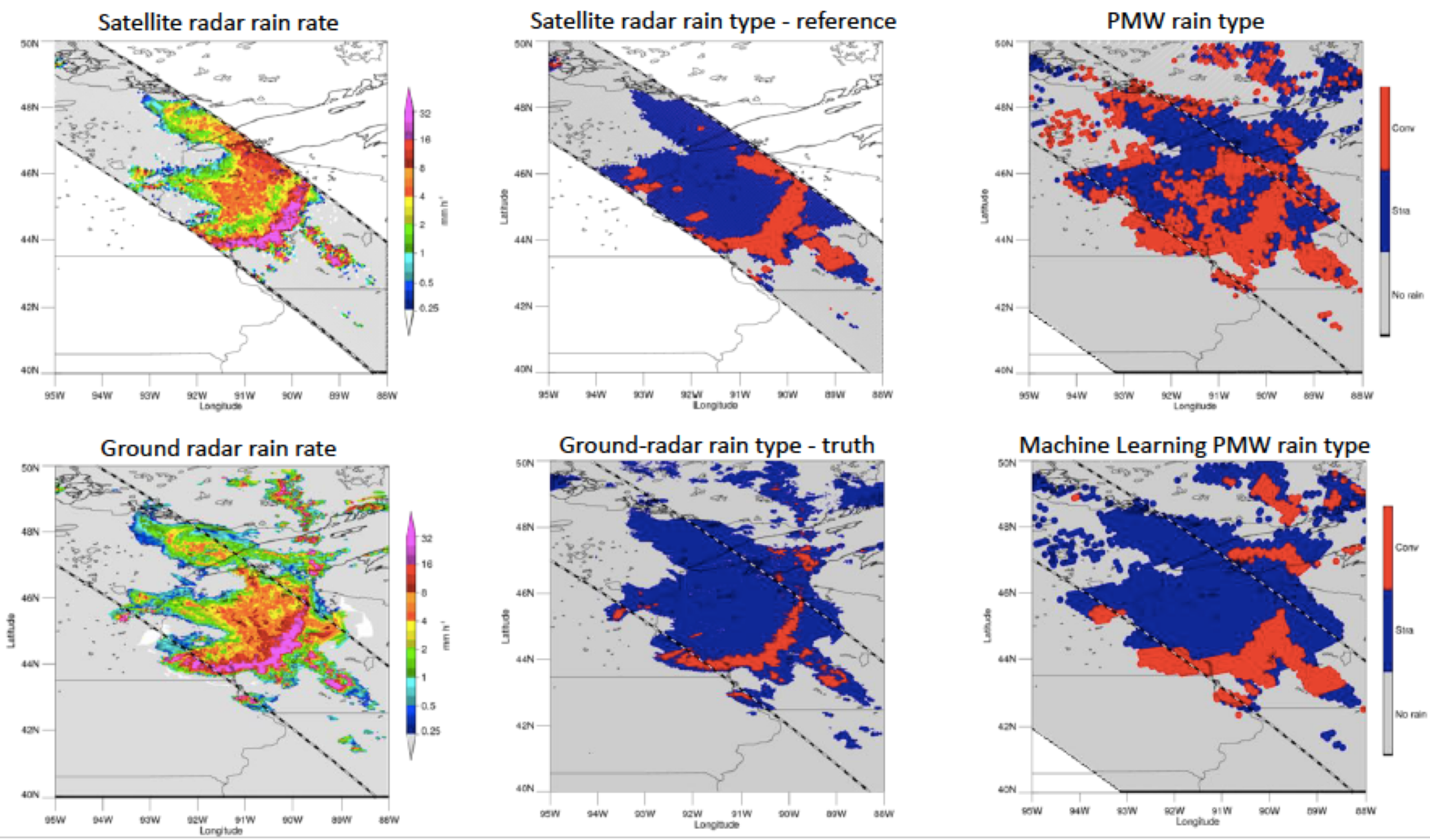
(The hard part)

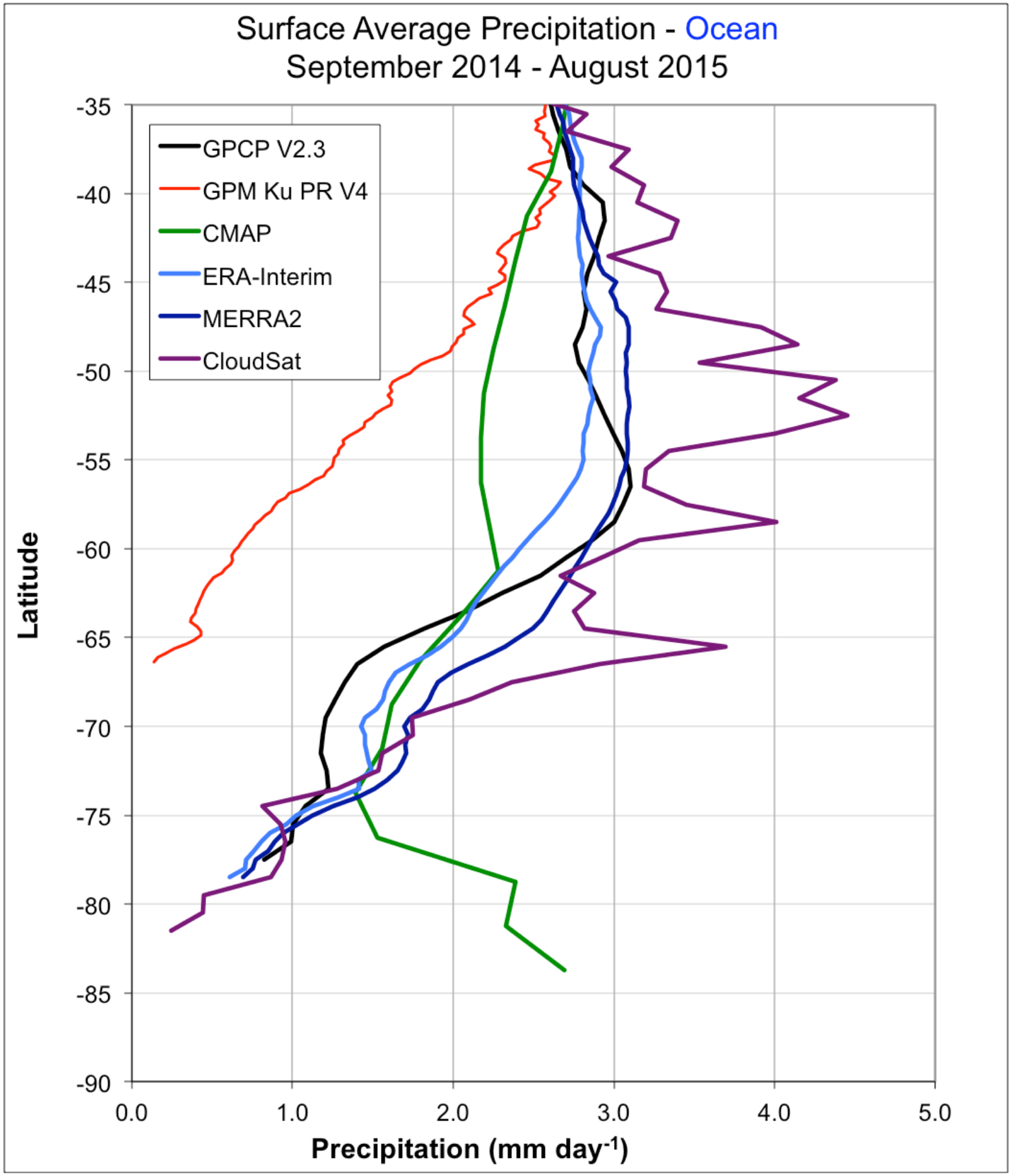
✧Optimal Estimation is currently run over oceans only. Will assess if NOAA's MIRS algorithm can be used for non-precipitating scenes over land.
✧Neither DPR, nor OE currently do oceanic drizzle very well. Recent paper by David Duncan. Rick Schulte Ph.D. to focus on this problem. W. Christian Klepp, Paul Kucera, Brenda Dolan/Steve Rutledge, Joe Munchak
✧Precipitation over snow is not well depicted by any product. Plan to continue using observed database from MRMS.
✧Exploring matched FOV for more physical relationship between physical parameters and Tb.

The Retrieval

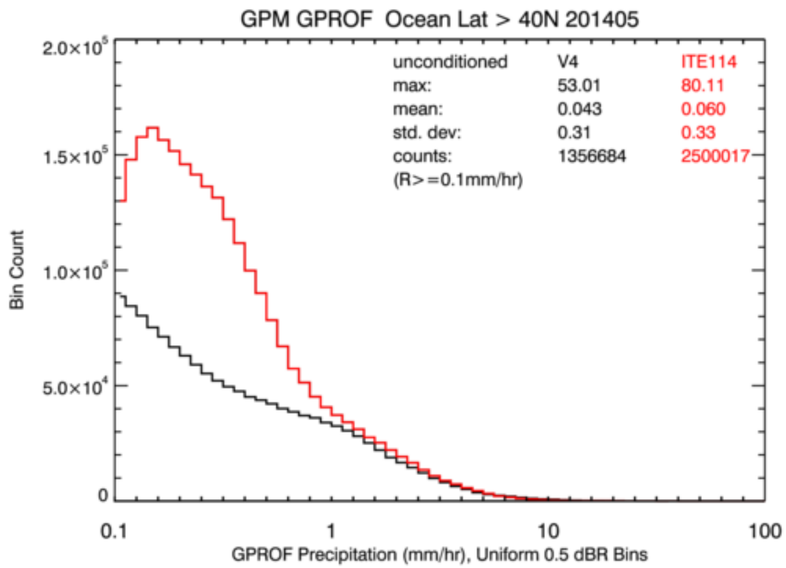
Mechanics are fine but need to determine if there is enough information in the radiance vector or if additional *a-priori* information is necessary/desirable.

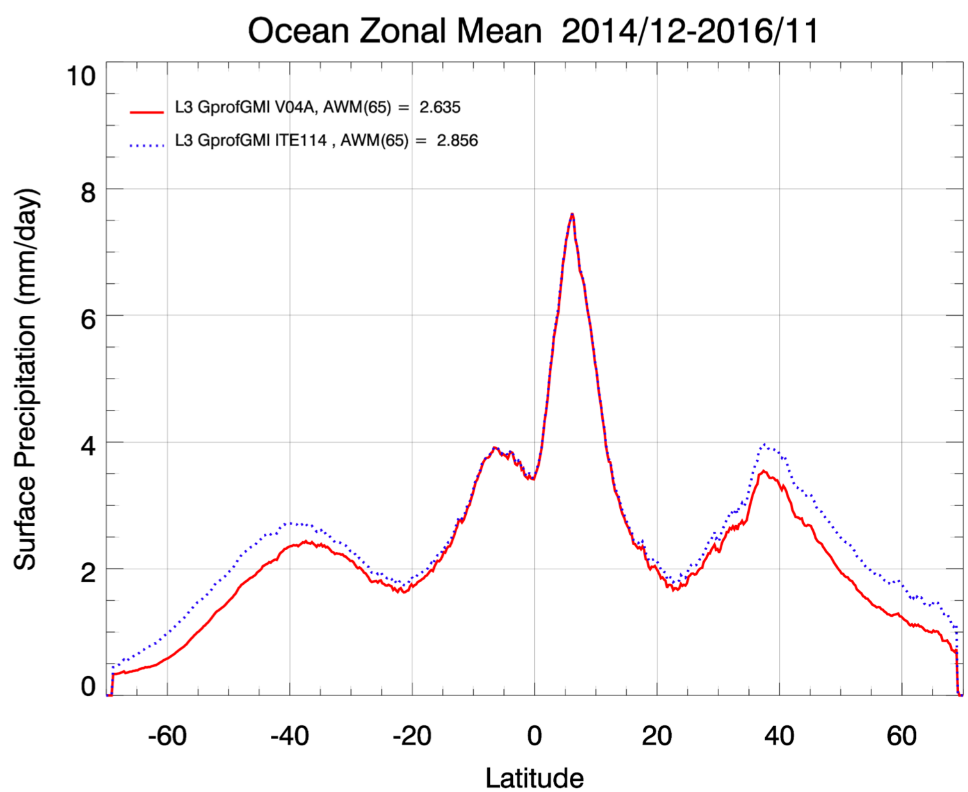
- Convective /stratiform rain types
- High latitude ocean drizzle
- Snow / orographic precipitation


Satellite radar rain rate
Satellite radar rain type - reference
PMW rain type
Ground radar rain rate
Ground-radar rain type - truth
Machine Learning PMW rain type
Longitude
Latitude
Conv
Stra
No rain



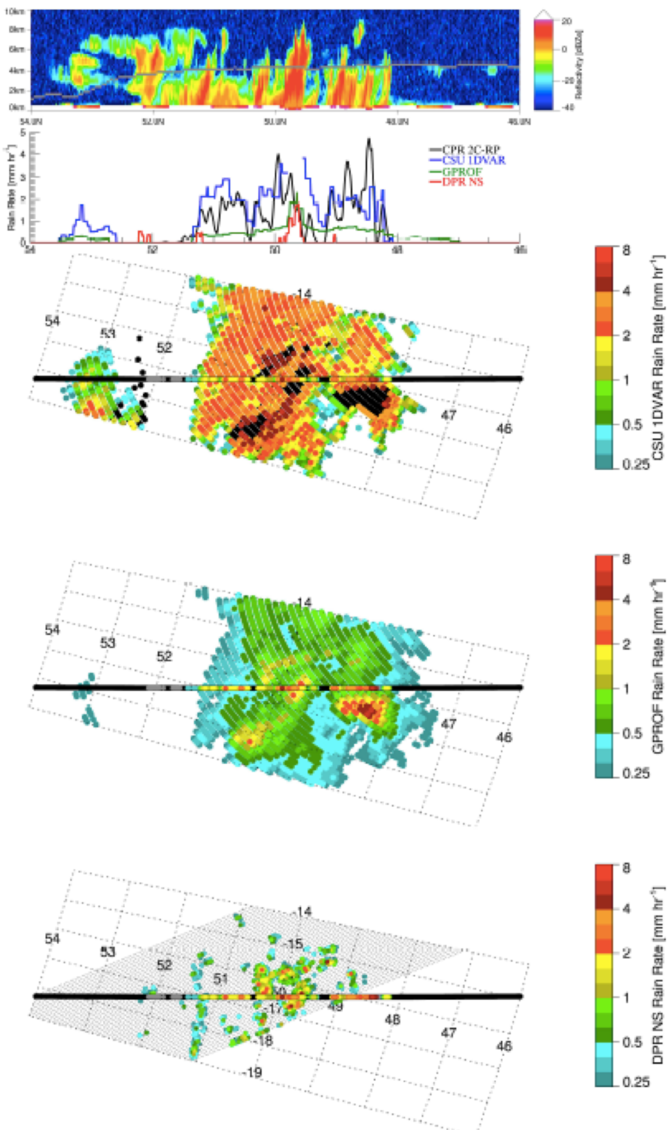
Surface Average Precipitation - Ocean
September 2014 - August 2015
GPCP V2.3
GPM Ku PR V4
CMAP
ERA-Interim
MERRA2
CloudSat
Latitude
-35
-40
-45
-50
-55
-60
-65
-70
-75
-80
-85
-90
0.0
1.0
2.0
3.0
4.0
5.0
Precipitation (mm day-1)

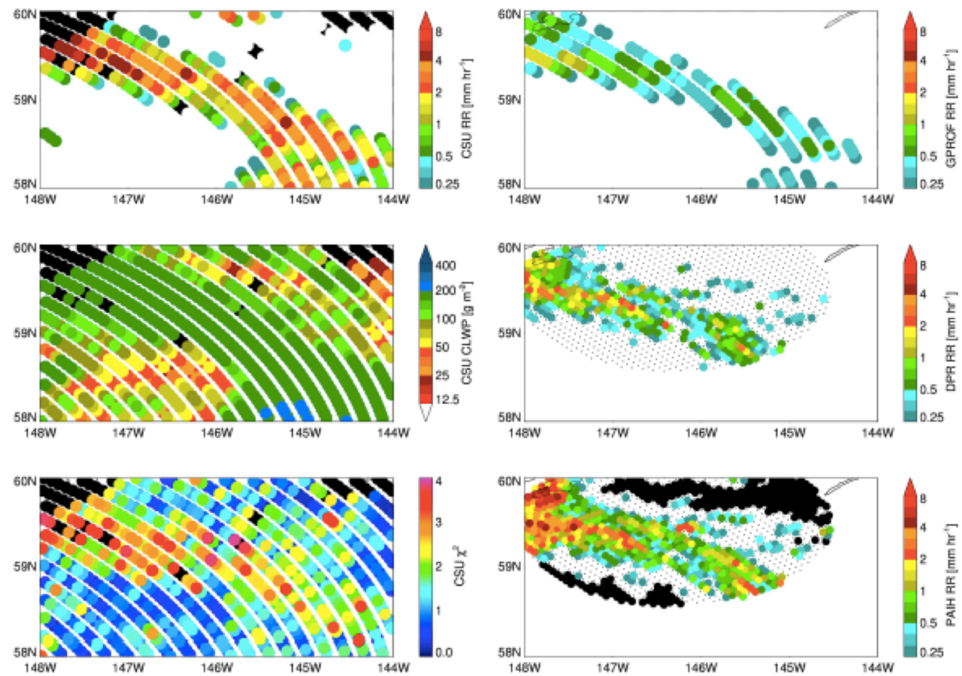

GPM GPROF Ocean Lat > 40N 201405
unconditioned V4 ITE114
max: 53.01 80.11
mean: 0.043 0.060
std. dev: 0.31 0.33
counts: 1356684 2500017
(R>=0.1mm/hr)
Bin Count
2.0×10^5
1.5×10^5
1.0×10^5
5.0×10^4
0
0.1
1
10
100
GPROF Precipitation (mm/hr), Uniform 0.5 dBR Bins


Ocean Zonal Mean 2014/12-2016/11
L3 GprofGMI V04A, AWM(65) = 2.635
L3 GprofGMI ITE114 , AWM(65) = 2.856
Surface Precipitation (mm/day)
10
8
6
4
2
0
-60
-40
-20
0
20
40
60
Latitude

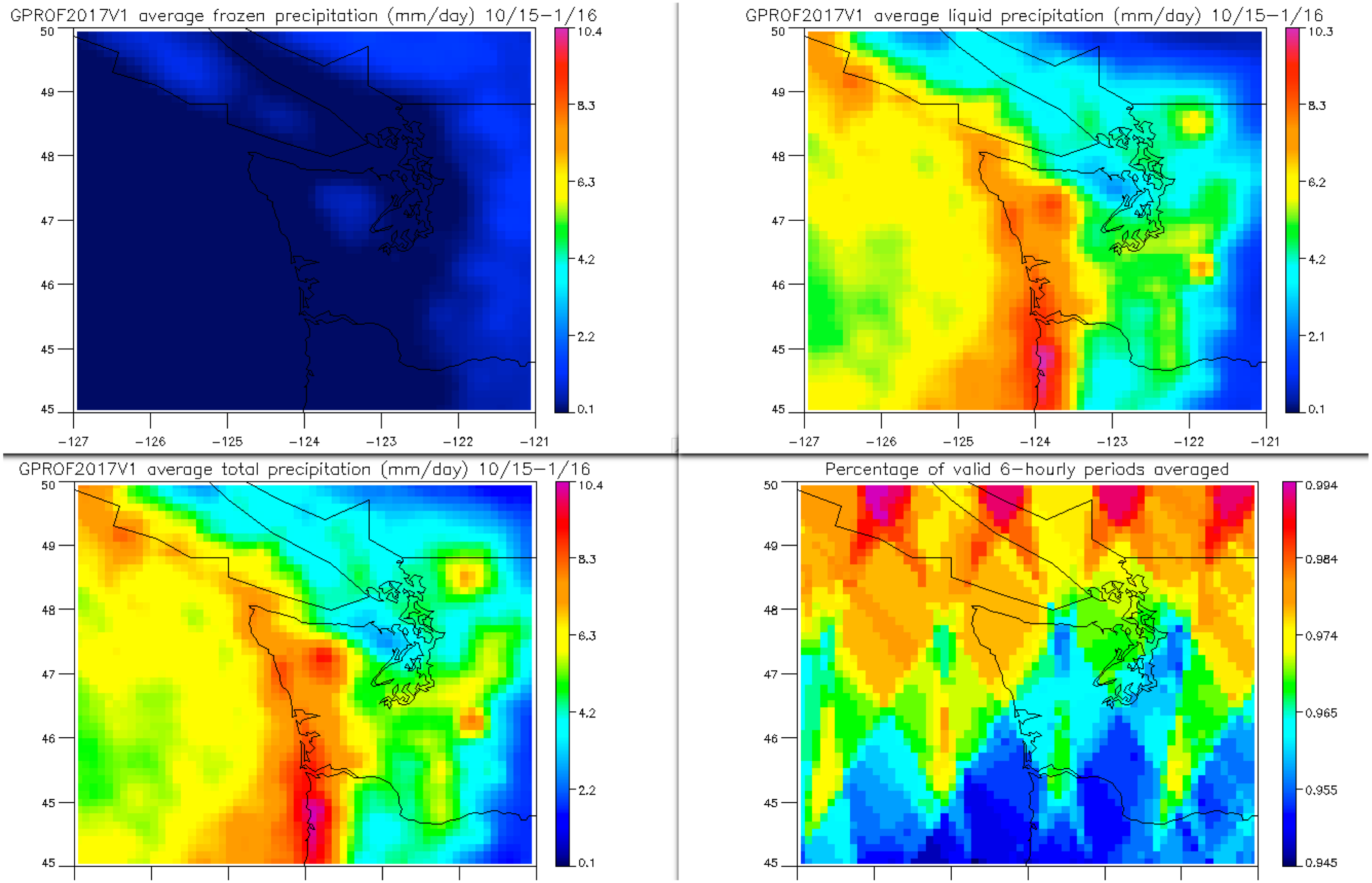
OE with drizzle

Constrained by observed DSD





V5 comparisons w. Olympex snow



CRB-GPROF Bias Adjustment

- Climatological bias (Oct 2001 – Sep 2017) of sensors determined by comparison with gauges (Figure 3) during rain (May-Oct) and snow (Nov-Apr) seasons in the CRB.
- Bias adjustments are made by multiplying CRB-GPROF precipitation estimates by the values in Table 1.
- Snow season precipitation estimates from the PMW are consistently underestimated.

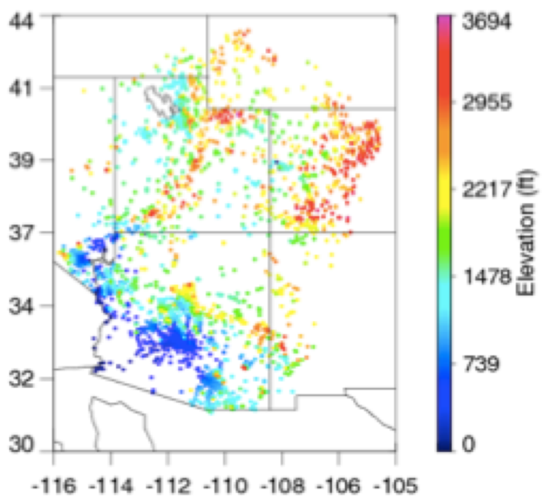


Figure 3 Colorado River Basin gauge locations and elevations, obtained from the CBRFC.

Table 1 Climatological bias adjustments (Oct 2001 – Sep 2017) calculated for PMW sensors over the CRB for the rain (May-Oct) and snow (Nov-Apr) seasons.

SENSOR	RAIN SEASON	SNOW SEASON
AMSR2	1.50	3.95
AMSRE	1.66	3.86
ATMS	1.21	2.02
F13	0.99	3.43
F14	1.06	3.98
F15	1.08	4.01
F16	1.07	2.84
F17	1.18	2.65
F18	0.99	2.78
F19	1.09	2.72
GMI	1.01	2.70
METOPA	0.91	2.18
METOPB	0.92	2.13
NOAA15	0.73	1.95
NOAA16	0.96	1.94
NOAA17	0.99	2.17
NOAA18	0.83	1.80
NOAA19	0.86	1.97
TMI	1.29	3.22

Summary

Working towards codifying database creation. Objective is to eventually make automated updates when DPR-Combined algorithm improves.

Classification schemes that use Machine Learning seem to work quite well. Examples from HSAF also.

Still working on improving some areas where radiometers do not enough information.